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Overview of Prairie Planting Techniques and Maintenance Requirements

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INTRODUCTION: This technical note provides an overview of techniques and maintenance requirements recommended for establishing and maintaining prairie lands. It serves as a product for the Ecosystem Management and Restoration Research Program (EMRRP) work unit titled "Prairie/Grassland Ecosystem on Corps Projects" and is meant as a general guideline. In most cases, a prairie site takes at least five years to develop to maturity, which is an important point to understand before undertaking a prairie restoration project (Shirley 1994). It takes time for the plant community to develop, for species diversity to increase, and for the area to regain function as a prairie ecosystem. Thus, careful planning prior to planting will make the prairie planting more successful (Figure 1). The following concerns must be addressed when planning a prairie restoration project:

- What type of ecosystem it is; what type of plant life and wildlife does it support?
- What is the goal appropriate to the type of prairie system being restored?
- What is the future management of the prairie area and what are the appropriate tools to achieve the management objective?
- Will burning be permitted in the area and can a burn be conducted at the time of year deemed necessary to maintain the prairie?
- Will the area be impacted from future development?
- Are invasive species present in an existing prairie and if so, has the cost for eradication been considered?

Figure 1. Prairie management site on Corps lands at Tuttle Creek Lake, Kansas (photo courtesy of P. Bailey)

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These questions and others must be considered when developing plans for burning, mowing, and maintaining a prairie.

Given the variation in prairie lands under Corps jurisdiction, there are many regional specifics this note cannot adequately address; therefore, recommended timelines are general. This technical note is organized into three major topic areas:

1. Planting techniques, including site preparation, timing, soil, seed mixes, treatments such as over-seeding, mosaic seeding, planting, and invasive species control.

2. Maintenance tools and techniques describing the use of fire, mechanical means, grazing and fencing.

3. Monitoring the restoration area.

PLANTING TECHNIQUES:

Site Preparation. When preparing for a prairie area planting, it is critical to reduce competition from weeds before planting. Regional differences defined by temperature zones, aspect, topographic location and local geomorphology affect timeframes for planting windows and maintenance events. Areas can be tilled in the early spring by shallow disking every three weeks to eliminate weed competition until the area is planted. This should be followed by final disking using a field harrow to level the field and break up clods. The final step should be rolling the soil to obtain a firm surface. Rolling the surface parallel to the contour provides the best protection against water erosion when the soil is unprotected by vegetation. Plant or crop residue can be left on the surface to further protect the soil from erosion. It is generally not necessary to apply fertilizer to a prairie planting because fertilizer will stimulate competition from unwanted weedy annuals. If a stand of prairie grass exists on the site, consider using a seed drill instead and interseeding rather than cutting the roots of existing plants, which leads to gradual thinning of the grassland (Manske 2006). Mowing the area before annuals produce seed will also help control weed problems. Once established, native grasses and forbs will inhibit weed growth (Figure 2).

Timing. The timing of planting is important and differs from region to region depending on location and type of prairie ecosystem. Successful stands of prairie species have been planted in the spring, summer, and fall. Most spring-blooming species germinate best when planted shortly after collection while other species do better when planted in early spring, late spring, or early summer. Most warm-season grasses, legumes and many composites do well in late spring plantings. In Kentucky, research has indicated that spring planting is preferred when soil temperatures reach 55 °F, and best germination occurs when soil temperatures reach 65 °F. (Barnes 1998). However, in the Midwest, research indicates that fall planting may be more successful and is increasingly being used in restoration projects in that region (Kurtz 2001). There are a number of reasons to plant in the fall, including less chance of erosion from early spring rains and less competition from weedy species. Another advantage of planting in the fall is that many seeds require cold stratification to germinate, which will occur over the winter as seeds sit dormant until the following spring. Seeding in late October and early November allows a variety of species of prairie plants to become established (Kurtz 2001).

Figure 2. Once established, native grasses and forbs will inhibit weeds (photo courtesy of C. Martin)

Soils. Understanding site conditions will aid in determining the best plants to be incorporated in a seed mix. Managers should identify the soil type and determine if the area to be planted is wet or dry, and whether it has steep or rolling topography. There will be specific management concerns for rocky and sandy soils. To find out about the soils in a particular area, check with the Natural Resource Conservation Service (NRCS) soil mapping database.

Topsoils in the Tallgrass Prairie region are rich in organic material and are often 20-28 in. deep. Grass roots fill several soil profiles extending to a depth of 5-7 ft and some forbs can grow as deep as 20 ft (Miller 1997). Approximately 65 percent of prairie plant biomass is below ground. As the roots decay they become organic matter in the soil; very little organic material is added to the top surface. Ants play an important role in mixing and aerating the soil by adding organic material throughout the depth of the topsoil and other soil strata (Miller 1997).

Seed mixes. Seed mixes can be purchased for varying light conditions and moisture and temperature regimes. For example, savanna mixes are composed of more shade-tolerant plants. The manager should consider selecting plants that grow in the local area to ensure a seed mix adapted to that particular environment. Diversity of the seed mix is also an important consideration since many prairie ecosystems are highly diverse. Visiting a local prairie and taking notes on the species present

and their phenology (e.g., time of flowering and seed production) is highly recommended to help with the design of specific seed mixes.

Once the species of grasses and forbs have been chosen for the mix, seeds can be collected or purchased. Hand-gathered seed sources can include collecting local ecotypes that naturally evolved at the site or as close to the restoration site as possible. Seed that is gathered farther away may be acceptable if there is nothing available closer. However, seed collected from different soil types or climatic regions may have lower survival rates than local seed. Harvested seed can also be added to commercially purchased seed. Native grass seed is often sold pre-mixed, but the authors recommend that individual species lots be purchased and mixed together prior to planting; this will result in the desired mix using the best quality seed. Small quantities of seed are most easily mixed in a 5-gallon bucket. Larger amounts of seed should be mixed on a clean smooth concrete floor, using grain scoops to turn the seed pile. It is easier to keep smooth seed together in one mix separated from fluffy seed; they can be planted in the same area using different seeding rates.

Using certified seed is recommended because the seed has known identity and meets certified quality standards for purity and germination (Natural Resource Conservation Service (NRCS) 2006). This has the best chance of success and least chance of introducing unwanted seed problems. Varieties of seed have been developed and proven by the NRCS for specific geographic regions of the country. Native grass seed (and often wildflower seed) is sold on a pure live seed (PLS) basis and is recommended because it ensures that the desired product is what is being paid for, and protects against procurement of dead seed or unwanted plant pieces. A pound of pure live seed contains 16 ounces of living seed of the desired species plus additional weight of the other material that has not been removed by the cleaning processes. Using the seed analysis tag, the PLS can be calculated to compare quality of "lots" of seed (NRCS 2006). For example, a seed lot with a tested germination of 80 percent and a purity of 90 percent also has a PLS percentage of 72 ($0.80 \times 0.90 = 0.72$). In 1.0 PLS pound of this seed lot, the gross weight to buy and plant would be 1.39 lb (1.00 divided by 0.72) (NRCS 2006).

For additional information on seed sources, refer to the technical note on regional availability of plants for prairie restoration (Bailey and Martin 2006). Table 1 shows the adaptability of selected prairie grasses to various site conditions.

Table 1.
Species Adaptability to Various Site Conditions (Adapted from Barnes (1998)).

Shallow or Ridge-top soils	**Mesic Well-drained Soils**	**Bottomland Soils**
Side- Oats grama	Little Bluestem	Prairie Cordgrass
Little Bluestem	Big Bluestem	Eastern Gamagrass
Prairie Dropseed	Indiangrass	Indiangrass
Needle and thread	Switchgrass	Western Wheatgrass
Buffalo grass	Sand Dropseed	Sprangletop

Ratios of forbs to grasses will vary in commercial seed mixes; typical mixes include ratios of 50/50 or 60/40 and 66/33 forb/grass seed. The more diverse the seed mix (number of species within the mix), the more stable the prairie will become over the long term. For purchased seed it is better to

buy a grass mix and a forb mix separately and create a custom mix to ensure that the most desired species are acquired. If legumes are used in the forb mix, make certain that the appropriate inoculant is included with the seed.

Seed harvested from native stands may vary considerably from one season to the next in quantity, quality, and species diversity. To increase diversity in the planting, it is recommended that the manager use seed that is harvested in two different years (Kurtz 2001). Once gathered, the seed needs to be dried, threshed, separated from the heads, and properly cleaned and stored. Seed should be dried shortly after harvesting to prevent loss during storage. Properly dried seeds have a 5- to 14-percent moisture content during storage (Harrington 1972). When seeds are dried out below 5 percent, their cell walls break down and enzymes become inactive, and seeds with a moisture content from 14-30 percent are often lost to microorganisms and fungi. Moisture levels above 30 percent will induce germination (Apfelbaum et al. 1997). Seeds often need treatments replicating natural processes to germinate well. Interseeding an area already planted or partially established during the following year will increase the diversity of the planting, because some species do not grow well in an open seedbed. Seeding rates are variable and depend on the species composition of the mix. If the seed is purchased, recommendations are generally provided for the mix. For hand-collected seed, a general seeding rate guideline is 10 lb of clean, pure seed per acre and may be as high as 30 lb per acre for rough, clean, hand-collected seed (Diboll 1997). Rate will vary depending on the species chosen.

Depending on the composition, it can take a number of years for the mix to develop into a mature stand of prairie plants, and the stand will constantly change throughout its development process. Prairie plants do well in soil with a topsoil layer and are able to grow tall and lush once established. However, competition from weeds is greater in more fertile soils and will make the initial establishment more difficult. In soil that is less fertile, prairie plants will out-compete weedy species, but will not grow as vigorous as they would in better soil. Warm season grasses, such as the bluegrasses, are more difficult to establish, but once established are more productive than cool season grasses. They offer better nesting and cover for quail, songbirds, and rabbits and also provide better winter cover.

Seed treatments. Various seed treatments may be necessary for proper germination. Treatments include sowing fresh seed, cold moist stratification, warm moist stratification, cold dry stratification, inoculation, scarification, light treatment, and vegetative propagation. Treatment methods are briefly described below:

- Sowing fresh seed works well for most spring flowering species. Seeds can be sown in flats to be set out when they have developed.

- Cold moist stratification can be accomplished by mixing seed with damp sand or vermiculite. The mixture is placed in a plastic bag and put into a refrigerator where the temperature is 34-40 °F. Species differ on how much time they need to be stratified; some will require 10 days, while others will require 120 days, but for most species 60-90 days is typical ((Kurtz 2001). Once the treatment is achieved, planting should take place in mid-spring when the outdoor temperature is warming up. Species that require stratification can also be sown directly outside in the fall.

- Cold dry stratification requires that dry seed be placed in a plastic bag and put into cold storage for a period of time.

- Warm moist stratification can be done by mixing seed with damp sand or vermiculite, then placing the seed in a plastic bag and warming to 68-75 °F.

- Scarification is the process of physically breaking down seed coats, so the plant embryo can take up water and begin to grow. Seeds can be scarified with a piece of sandpaper or by soaking in acid baths, which mimics the natural process of being eaten by an animal and broken down within the digestive system.

- Inoculation of legumes with nitrogen-fixing bacteria enhances growth. Bacteria are applied to wet seed just before it is planted (Steffen 1997). Full sunlight is needed for some seeds that require light to break dormancy and these species can be sown on the surface of a firm smooth seedbed. Some plant species have complex propagation requirements and require combining the above techniques in a particular pattern.

- Vegetative reproduction is the process of dividing roots and planting pieces of the parent plant to create other individuals.

Interseeding. Interseeding refers to the process of planting seed directly into existing vegetation without plowing or herbiciding. This method is preferred where there are many conservation species in an area to be preserved and can serve to increase diversity in the planting. Compared to plowing, plant establishment by overseeding takes considerably longer because of competition from existing plants. A seed mix will develop slowly over 4-5 years when a site is interseeded. A recommended approach for restoring a degraded prairie site consists of conducting prescribed burns for 2 to 5 years followed by interseeding with an appropriate seed mix (Kurtz 2001). The primary benefits of interseeding include the relative ease with which many conservation species are restored, improvement in site quality, and the potential contribution to biodiversity conservation (Packard and Mutel 1997).

Mosaic seeding. This technique involves various seeding rates and species mixes for different sites within the prairie restoration area. It allows for adjusting the planting to correspond to topography and the species continuum found along moisture and slope gradients. Additionally, mosaic seeding can be used to increase botanical diversity. For example, planting more forbs in an area may allow species to survive that will not compete well with grasses. Planting in this manner allows for unevenness or patches to develop, which mimics a natural prairie. These patches create different types of habitat and result in greater faunal diversity.

Planting. A no-till drill specifically designed for seeding the fluffy seeds characteristic of native grasses is recommended for prairie plantings (Figure 3). Native grass drills have double disk openers with depth bands and large-diameter drop tubes that don't allow seed to hang up in the tubes (NRCS 2006). Placing the seed at the proper depth is critical to planting success. The maximum proper seeding depth is ¼ to ½ in. (NRCS 2006); it is better to seed on the surface of the ground than for the seed to be buried too deep. Conventional drills do not have depth bands or feed mechanisms that can handle fluffy seed. Cultipacker type seeders will not meter the fluffy seeds and are not as effective in proper seed placement (NRCS 2006). Some soil and water conservation districts have these drills

available for rent. A three-point broadcast seeder or a fertilizer spreader can be used and will cover a 6-ft-wide strip. Care should be taken to ensure that the seed is spread uniformly. Once the seed is broadcast or drilled, the site should be harrowed lightly and rolled until the soil is firm; this will prevent the soil from washing away**.** A practice that is not favorable is disking the soil because it cuts the root biomass causing a flush of growth, then eventual thinning of the aboveground growth. This opens up the soil to weedy annuals (Manske 2006)**.**

Figure 3. A no-till drill is used for planting and interseeding an area, and causes minimal disturbance to existing plants (photo courtesy of Kurt Brownell)

Invasive species. Control of invasive species is critical for any type of restoration work. Encroachment by woody species is a particular threat to the prairie ecosystem because shrubs and other woody vegetation shade out grasses and forbs. Control methods include herbicide application, mowing, brush hogging, using tree shears, burning (discussed in the following section), and grazing. If the area to be restored is covered by an invasive species, control of existing stands using applications of an appropriate herbicide should be the first step. Establishing a prairie plant community may require ongoing surveillance and control of the invasive species. The ability to respond quickly, thus eradicating annual weeds before they go to seed, can make a significant contribution to invasive plant control.

During the first year of establishment, prairie plants primarily develop roots and aboveground growth is short. By contrast, weeds grow fast and tall in the first year, thus mowing during this period will help the prairie plants compete for light. However, it is important to set the mower height above the top of the prairie seedlings. Applying systemic herbicide treatments directly to unwanted herbaceous plant leaves or cut stems of brush and invading trees can help in keeping the area from undergoing succession. Most common agricultural weeds that occur in a new planting will become

reduced as the prairie grasses and forbs develop. Proper grazing management can also stimulate tiller formation and allow native grasses to become dominant. The formation of the root system of grasses into thick mats helps prevent further encroachment of invasive and undesirable species (Packard and Mutel 1997). It is important to avoid management practices such as plowing or disking, which expose the soil, thin the stand, and invite annual weedy species.

MAINTENANCE TOOLS AND MANAGEMENT: Prairies, savannas and their associated wetlands are fire-dependant ecosystems. Therefore, prescribed burns are a highly desirable maintenance practice. However, there are reasons for not being able to conduct prescribed burns on a routine basis. For example, it may not be possible to obtain a burn permit because the prairie is too close to adjacent land developments, which may not allow the area to be maintained by fire for safety reasons. Where controlled burns are not allowed, mechanical approaches must be used.

Fire. Fire is an integral part of the prairie ecosystem and is necessary for maintaining habitat quality and the most desirable balance of native prairie plants (Figure 4). Fire rejuvenates prairies and stimulates plants to grow taller, become more robust, flower more profusely, and produce more seed. Fire also lengthens the growing season for prairie plants but shortens it for many weedy species (Pauly 1997). Fire allows for nutrient recycling in the ecosystem by increasing available nutrients and adding nutrients by stimulating microbial activity in the soil. Ash also adds some nutrients back to the soil. Burning off the accumulated dead grass and exposing darker soil can cause the soil to heat up quicker in the spring, therefore lengthening the growing season. Most prairie plants have buds that lie just below the soil surface, so an early spring fire will not impact many plant species. Fire also controls the growth of woody shrubs and tree saplings.

Figure 4. A controlled burn in progress to maintain native prairie on project lands in the Kansas City District (photo courtesy of Mike Watkins)

Safety is paramount when using fire because atmospheric conditions can change quickly, causing fires to rapidly burn out of control. An experienced burn leader must plan and conduct controlled burns. Factors that must be considered when planning a burn are wind direction, wind speed, humidity, slope, and fuel characteristics such as the height, type, and amount of vegetation being burned. For example, a change in wind direction can cause a backfire (fire burning against the wind) to become a blazing head fire. If wind speeds double, the rate of fire spread will quadruple. As the ambient temperature increases and humidity drops, the fire temperature will increase. Establishing firebreaks between prairie areas, forested areas, and buildings is essential for safety.

A controlled fire burns in a narrow line moving quickly through the grass. As the grass litter is consumed the flame moves forward. In savannas, flames pass through the area quickly and do not generate enough heat to damage large trees; the fire simply passes around them. However, the presence of standing brush or dead fuels could create a hotter fire. Usually a line of fire carried by a head wind will be 5 to 15 ft wide with flames no more then 8 ft tall. A backfire (Figure 3) normally is about 1 ft deep and 1 ft high (Packard and Mutel 1997).

Fire is beneficial for most prairies. However, variables such as species of plants, types of prairies, environmental factors, and local ordinances affect how often a site should be burned. Timing the fire event is important and depends primarily on the management objectives. Early spring fires do not damage the underground buds of warm-season native plants and help to warm up the soil and release nutrients. The northern tallgrass prairie system is dominated by C3 (cool-season) plants, whereas the more southern mixed grass region of the central plains is dominated by C4 (warm-season) plants. C3 and C4 refer to the pathway of photosynthesis (Anderson 1997). Dormant season burns favor native C4 plants. Prescribed burns are often conducted when native and exotic C3 plants are actively growing in the spring or fall and C4 plants are dormant. These burn conditions retard the growth of C3 plants and enhance the dominant C4 prairie plants. In contrast, burning in July and August when C4 plants are actively growing and C3 plants have completed their period of most active growth will favor C3 plants.

Historically, the tallgrass prairie of the Midwest was exposed to fire set by Native Americans in the fall (Axelrod 1985). In contrast, mixed grasslands of the Great Plains were summer fires caused by lightning strikes, which occurred more frequently (McClain 1994). Spring burning can negatively affect nesting and breeding bird activities, which is a concern in some areas. Late spring burning is not recommended because burning green vegetation will create immense amounts of smoke and can make people sick if inhaled. If poison ivy is burned it can be a health threat to humans, especially if the smoke is inhaled.

In a tallgrass prairie system burning in the early spring when grasses are approximately 1 in. tall is preferred (Capel 1992). In shortgrass prairie systems, a dormant season fire may be preferable, particularly where fire has been excluded for long periods of time (Brockway et al. 2002). A more positive response to fire will occur where there is a greater accumulation of litter. Mesic prairies will accumulate litter faster then drier prairies. Mesic prairies generally need from one to three years to accumulate preburn levels of leaf litter (where leaf litter production equals decomposition), whereas dry prairies may require 4 to 6 years to reach preburn levels (Pauly 1997). At these intervals the fire will control shrub growth and will prevent succession from occurring. In a savanna a 3-year rotational interval is effective for maintaining a desirable open grassland understory. This will

prevent the accumulation of too much fuel, which would result in a fire that would burn too hot and cause damage to the existing trees. This is the case where evergreen trees are dominant such as in Longleaf Pine ecosystems. In Longleaf Pine systems, fire is necessary to cause the cone to open and release the seed (Figure 5).

Figure 5. Effects of three-year fire rotational management in a Longleaf Pine Savanna ecosystem which successfully supports threatened and endangered plant and animal species, N.C. (photo courtesy of P.Bailey)

Another consideration is to create a rotational fire management plan that will benefit plant and animal species. This is accomplished by dividing an area into equal proportions equivalent to the fire interval years. For example, if the total area is to be on a 3-year fire rotation, divide the area into thirds and burn one area each year (Pauley 1997). By planning a multi-year rotation, insects and small mammals can find refuge in the adjacent unburned areas, and plant seed disbursement into unburned areas can continue.

Refer to regulation ER30-2-540 for Corps guidance on prescribed burn plans for prairies. Ways of accomplishing prescribed burning include doing it in-house, partnering with other public agencies, outgranting, contracting and using local fire departments as volunteers. Corps staff or others performing controlled burns are required to be trained to conduct this type of work. To find out more on fire regulations, go to EP 1130-2-540, Chapter 2 (U.S. Army Corps of Engineers 1996) or the Gateway website at *http://corpslake.usace.army.mil/employees/fire/fire.html*.

Mechanical maintenance. Mechanical maintenance procedures will be required in small tracts of prairies that cannot be burned. Mechanical maintenance includes a combination of approaches

including mowing, brush hogging and using tree shears (Figure 6). Each fall or spring the dead vegetation and aboveground thatch can be mowed and raked off and the brush and exotic species can be weeded by hand. Obviously this approach is not feasible on a larger scale. Many high-quality prairies are mowed as hay, which is removed every year (dead thatch left on a site will cause some prairie species to disappear). However, haying reduces annual plants from the plant community and suppresses their seed, which may be undesirable depending on the goal of the planting. Haying also reduces soil fertility, which cannot be readily corrected. Mowing during the spring can also have negative impacts on the nesting and breeding activities of birds.

Figure 6. Tree shears are used to control the encroachment of woody vegetation on projects in the Kansas City District (photo courtesy of P. Bailey).

If there are weeds in the prairie planting the first year, the site should be mowed at a height of 10 in. in June and July. Make sure to mow above the grass seedling height. Cutting the woody growth and using a follow-up selective herbicide application on the stems and on other unwanted exotics will also aid in establishing warm season grasses. Brush hogs or tree shears may be necessary tools for this purpose. In August, discontinue mowing to allow growth and root development during late summer and fall (Manske 2006). During the second year, plan on cutting hay when it is in seed, leaving it about 10 in. high.

Grazing. Prairie ecosystems evolved with large grazing animals, such as herds of bison (*Bison bison*). Grasses and prairie plants have co-evolved with large grazing animals and have adapted to grazing. The adaptations are expressed through resistance mechanisms that plants have developed in response to evolutionary selective forces of defoliation (Manske 2006). To maintain adequate activity of these biological processes, healthy prairie and range plants require annual defoliation by grazing. Management that is focused on a single use and does not include annual defoliation at the appropriate growth stages cannot sustain a healthy ecosystem over time (Manske 2006).

Grazing intensity no greater than 30 percent during the optimum 45-day growth period from the first of June to mid-July will increase tillers and leaf development for both cool season and warm season grasses. However, heavier grazing pressure (over 30 percent) will de-stimulate the plant and decrease production (Manske 2006). Maximum production will be achieved with moderate grazing intensity and rotational grazing during this 45-day period. If grazing occurs in prairie restoration areas, warm season grasses should be allowed to grow to a height of 15 in. before animals are allowed to graze on the area. Once the grass is grazed down to about 12 in., animals should be kept off the area until plants grow back. Grazing plants below 12 in. reduces plant vigor. Warm season grasses cannot be grazed down to the ground because of damage to the stand, which will lead to plant declines. Heavy grazing by livestock substantially reduces the standing biomass of grass that normally serves as a fuel that carries fire (Brockway et al. 2002). The area should be allowed to rest in the fall before frost occurs. This will allow time for carbohydrates to be transferred from the leaves to the roots, enabling the plants to store up energy for a quick and vigorous start to the growing season. Winter grazing should be avoided because grazing during this period damages the fall buds and tiller growth.

Patch burning grazing system. This system uses both fire and grazing to achieve the desired outcome. Originally this method was used on large acreages with bison, encouraging rotational grazing in lieu of fencing. Currently others are investigating using this system with cattle on smaller acreages (Helzer and Steuter 2005). Fire lanes and backfires are used to burn specified areas located throughout a compartment. The grazers ignore the older unburned foliage, preferring areas that have new green growth following a burn. The burning of “patches” can be rotated at different locations and seasons, uniformly distributing grazing over the entire area. Burning results in intense grazing pressure during the first year, which opens up space between the dominant grasses for new growth of forbs, particularly annuals and biannuals. The weedy forbs become dominant during the next year or two, then slowly subside from the recovering perennial grasses (Helzer and Steuter 2005). This technique can be used in an area where maintaining high plant diversity is desirable.

Protection of fragile areas by fencing. Potholes and vernal pools are examples of fragile areas within a larger prairie ecosystem. These areas often have many rare species of plants and animals in association. One effective way to avoid habitat alteration is to provide livestock fencing around the area to be protected. The area can be maintained by fire or other means, but is protected from grazing pressures and trampling of livestock that use the area as a source of water. Additionally, if there are any threatened and endangered plant species, locations may need to be fenced off to protect these populations.

MONITORING PLANS: Monitoring restored prairie sites is necessary to evaluate the restoration effort and determine the success of project goals. Vegetative monitoring is best accomplished by establishing permanent plots to record species present and percent cover in order to understand rates of succession and results of maintenance efforts. As the site develops, maintaining records of species diversity, percentages of cover, and other aspects of monitoring will aid in understanding site dynamics. A manager should ask the following questions regarding the site:

- Which of the planted species germinated and grew?
- Which plants came in from wild sources?
- What is the percentage of native species versus non-native exotic species?

- How are treatment techniques working on any invasive species present?

If the prairie has been planted to meet a specific goal, such as increasing habitat for a particular animal species, parameters can be added to analyze wildlife and the desired outcome. When threatened or endangered species are present, they need to be monitored to determine that the population is stable or increasing. If the population declines, a change in management strategy must be undertaken. The timing of the monitoring program will be dictated by the goals and factors, as stated above, and is ideally accomplished at the same time annually or biannually for a series of years. Examining overall successes and failures will provide a better understanding of the restoration process in a particular region, so that restoration methodology and maintenance practices can be improved or adjusted.

CONCLUSIONS: Corps of Engineers operational projects include a diversity of prairie habitats in different geographic regions. Approximately 750,000 acres of grasslands have been documented for Corps projects (Martin and Peloquin 2005) and there are many opportunities for improving these sites through appropriate restoration practices. Prairie restoration requires time and dedication in order for the process to be successful, and it generally takes at least 5 years for prairie to develop to maturity. This technical note outlines some basic strategies for the Corps manager to consider when planning a prairie improvement project. The report focuses on some basic techniques and approaches that can be applied to a variety of grassland sites. Management techniques and application methods will vary among and within regions based on specific site conditions.

The following basic steps must be taken to achieve successful prairie restoration:

- Understand the local ecosystem in the area to be managed.
- Define management objectives.
- Use tools appropriate for achieving management objectives.
- Develop an appropriate maintenance program (including consideration for burning, mowing, etc.).
- Design a monitoring plan to evaluate the success of the project.

These steps are only a starting point for prairie restoration, and more specific guidance will be needed for different regions of the country. Implementing a prairie restoration project that includes routine site inspection and attention to detail will allow the manager to obtain essential information about the ecology of the area and result in better strategies for improving and preserving biodiversity.

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SUMMARY: Prairie restoration on Corps projects will increase the extent of rare and valuable prairie ecosystems while providing a unique opportunity to improve habitat for a significant diversity of plants and preserve the gene pool of various plant species. This technical note provides

information relevant to the science of plant conservation and summarizes site preparation methods including timing, soils, seed mixes and treatments, over-seeding, mosaic seeding, planting, and invasive species control. The section on maintenance tools and management provides recommendations for fire management, mechanical methods, grazing, and fencing. Examples of regional variation in planting and management techniques are provided for most techniques. Lastly, the need for a monitoring program is discussed, especially on sites where threatened and endangered species occur, and basics of vegetative monitoring are described. Corps personnel should use this technical note as a general guideline prior to initiating a prairie restoration project. Detailed area and site information should be obtained from local sources before completing a restoration management plan.

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> Bailey, P., and C. O. Martin. 2006. *Prairie planting techniques and maintenance requirements*. EMRRP Technical Notes Collection (ERDC TN-EMRRP-ER-05). Vicksburg, MS: U.S. Army Engineer Research and Development Center.

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